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"The Hive and the Honey Bee"

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CHAPTER XVII
HONEY

by J. W. WHITE, JR.*

WHEN PREHISTORIC MAN reached deep into a bee tree or a cleft in the rocks for a highly prized store of honeycomb, he must have felt that the prize was worth the price in stings from the outraged bees. Veneration of the bee and its products, honey and wax, can be traced through the entire span of man's record; honey has been an article of commerce for many thousands of years. As such, many definitions and standards have attempted to describe it. Honey is a sweet, viscous liquid prepared by bees from nectar collected from plant nectaries and stored by them for food. This definition excludes honeydew, which does not originate directly from nectaries (floral or extra-floral) but either from plant secretions (manna) or more commonly from the excretion of certain hemipterous insects (aphids, leaf hoppers, scale insects). While feeding on plant sap, these insects excrete from the alimentary canal a sweet liquid that is sometimes gathered by bees and stored for food, during partial or total absence of a nectar supply. More will be said of honeydew later in this chapter; sufficient now to note that it differs in most of its properties from honey.

The Food and Drug Administration does not have an official definition of honey. The former definition, in force under the original Federal Food and Drug Act of 1906, held that "Honey is the nectar and saccharine exudation of plants, gathered, modified and stored in the comb by honey bees *(A. mellifera* and *A. dorsata);* is levorotatory, contains not more than 25 per cent water, not more than 0.25 per cent ash, and not more than 8 per cent sucrose." The Food, Drug, and Cosmetic Act of 1938, which supersedes the original law, provides for definitions and standards of identity for foods. It has none for honey. The older definition is still considered by the Food and Drug Administration as an informal description of what honey should be, though it has only advisory status. Feinberg (1951) and White *et al.* (1962) have noted that it is unrealistic in its limits for moisture (too high), sucrose (too high), and ash (too low). Many states follow the Federal definition for honey, though some vary in moisture content and density requirements. It is advisable to become familiar with state food and drug requirements for honey, as well as state grading requirements, before packing honey even on a small scale.

Kinds of Honey

Honeys are classified by the principal sources from which the bees gathered the nectar. Although bees may work only one plant source at a time, the chances are that there is nectar from several plant types

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in most honeys. Ordinarily, honey is identified by one or more prominent floral-source names as "gallberry honey" or "alfalfa honey," or by two names, as "sage-buckwheat honey" (Fig. 1). Other less specific names are also used, such as "fall flower" and "spring blend." It has been held by the Food and Drug Administration (Herrick, 1948) that honey may not be labeled with the name of a plant or blossom except where the particular plant is the chief floral source of the product.

Another system of classifying honey is by method of production and preparation for market:

1. **Extracted honey** (also known as strained honey) is honey that has been separated from the comb by centrifugal force, gravity, straining, or by other means. It may appear on the market in different forms:

a. **Liquid honey** is honey that is free of visible crystals.

b. **Crystallized honey** is honey that is completely granulated or solidified, including products known as "candied," "fondant," "creamed," or "spread" types of honey. Such crystallization may be natural, i.e. with no added fine-crystal "starter" honey, or produced by one of several controlled crystallization processes.

2. **Comb honey** is honey contained in the cells of the comb in which it is produced. It appears on the market in several forms:

a. **Section comb honey**, produced in squares $4\frac{1}{4} \times 4\frac{1}{4} \times 1\frac{7}{8}$ inches or rectangles $4 \times 5 \times 1\frac{3}{4}$ inches, called sections. Such novelty forms as circular sections may be seen.

b. **Individual section comb honey** is produced in small sections, usually one quarter the size of ordinary sections.

c. **Bulk comb honey** is comb honey produced in shallow extracting frames fitted with thin super foundation. These combs may be sold when filled as complete units.

d. **Cut comb honey** is bulk comb honey cut into pieces of various sizes, the edges drained or extracted, and the individual pieces wrapped in cellophane or polyethylene bags.

e. **Chunk honey** consists of cut comb honey packed in a container which is filled with liquid extracted honey. For U.S. Fancy and No. 1 chunk honey, not less than 50 per cent by volume of comb honey must be present in the container.

The United States Department of Agriculture has established voluntary grade standards for extracted and comb honey.* These standards are designed to serve as a convenient basis for sales, for establishing quality control programs and for determining loan values. They also serve as a basis for the inspection of honey by the Federal Inspection Service. Standards have been established for extracted honey including crystallized

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*Copies of grade standards for extracted honey (fourth issue, effective April 16, 1951) and comb honey (second issue, effective August 1933) may be obtained from the Processed Products Standardization and Inspection Branch, Fruit and Vegetable Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington 20250, D.C.

honey, and for comb honey, including section comb, shallow-frame comb, wrapped cut comb, and chunk or bulk comb honey.

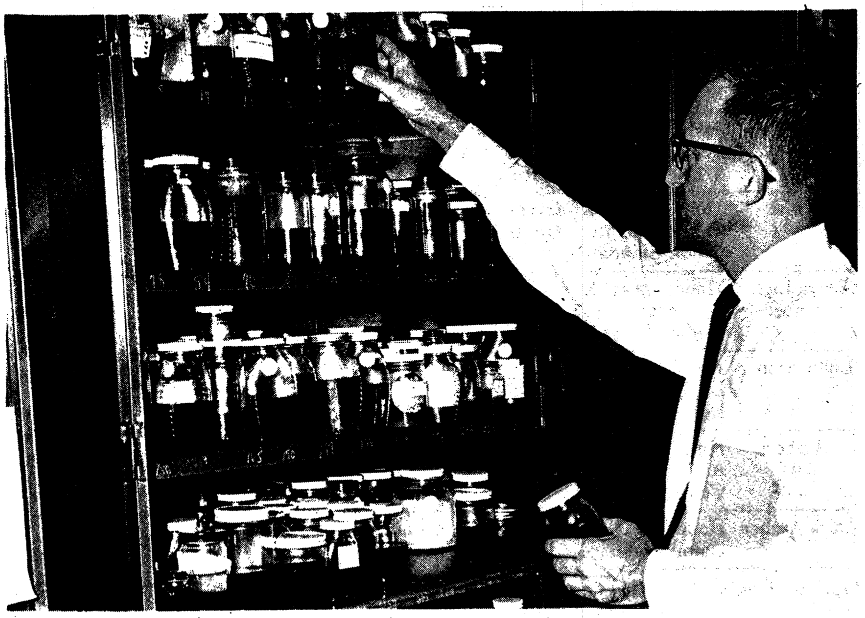

Figure 1. Dr. White examines the color of some of the 490 samples collected by the Honey Investigations Unit for their extensive study of U. S. honeys. *(U.S.D.A. photo by M. C. Audsley)*

For extracted honey, there are four classes: U.S. Grade A or U.S. Fancy, U.S. Grade B or U.S. Choice, U.S. Grade C or U.S. Standard, and U.S. Grade D or Substandard. Factors considered in grading are flavor, clarity, absence of defects, and moisture content. The first of these, flavor, refers to the prominence of honey flavor and aroma and its conformity to that of the predominant floral source. Clarity is concerned with freedom from pollen grains, air bubbles or other suspended materials. Absence of defects refers to degree of cleanliness and absence of particles of comb, propolis, or other materials. To qualify for the top two grades, honey must contain not more than 18.6 per cent moisture; Grade C may contain up to 20 per cent.

Color of honey is not a quality factor. It is measured by means of the U.S.D.A. permanent glass color standards or by the Pfund honey color grader. In Table 1 are the seven color classes of honey as defined in the U.S.D.A. grades.

Comb honey is classified as U.S. Fancy, U.S. No. 1, U.S. No. 2, and Unclassified. The factors considered in grading are appearance of cappings, attachment to the section, uniformity of honey, and absence of pollen, granulation, honeydew, or off-grade honey.

honey, building up the level of yeast contamination rapidly as the moisture diffuses into the honey.

TABLE 2. Composition and Physical Properties of Extracted Honey*

One pound (453.59 g.) of average American extracted honey would contain the following materials:

Principal Components	*Per cent*		*Grams*	
Water (natural moisture)		17.20		78.0
The sugars of honey				
Levulose (d-fructose; fruit sugar)	38.19		173.2	
Dextrose (d-glucose; grape sugar)	31.28		141.9	
Sucrose (common table sugar)	1.31		5.9	
Maltose and other reducing disaccharides	7.31		33.2	
Higher sugars	1.50		6.8	
Total sugars	79.59	79.59	361.0	361.0
Acids (gluconic, citric, malic, succinic, formic, acetic, butyric, lactic, pyroglutamic, and amino acids). Total acid calculated as gluconic acid.	0.57		2.6	
Proteins (nitrogen x 6.25)	0.26		1.2	
Ash (minerals: potassium, sodium, calcium, magnesium, chlorides, sulfates, phosphates, silica, etc.)	0.17		0.8	
Total acids, protein, and ash	1.00	1.00	4.6	4.6
Minor Components		2.21	10.0	10.0
Pigments (carotene, chlorophyll and chlorophyll derivatives, xanthophylls)				
Flavor and aroma substances (terpenes, aldehydes, alcohols, esters, etc.)				
Sugar alcohols (mannitol, dulcitol)				
Tannins				
Acetylcholine				
Enzymes:				
Invertase (converts sucrose to dextrose and levulose)				
Diastase (converts starch to dextrins)				
Glucose Oxidase (converts dextrose to gluconolactone)				
Catalase (decomposes hydrogen peroxide)				
Phosphatase (decomposes glycerophosphate)				
Vitamins (thiamine, riboflavin, nicotinic acid, vitamin K, folic acid, biotin, pyriodoxine — in small and variable amounts)				
Totals		100.00		453.6

*The average of the analyses of 490 samples of honey, by Honey Investigations Unit, Plant Products Laboratory.

68° (20°)

Specific Gravity 68°F. (20°C.) = 1.4225, corresponding to: 81.25° Brix at 60°F., 43.19° Baumé (Modulus 145) at 60°F., 84.6° Twaddel.

1 gal. weighing 11 lb., 13.2 oz. average.

1 lb. having volume of 10.78 fl. oz. (318.9 ml.).

Caloric Value—1 lb. = 1,380 calories, 100 g. = 303 calories, 100 ml. = 432 calories, 1 tbsp. = about 60 calories.

Refractive Index—1.4935 at 68°F. (20°C.), 1.4924 at 77°F. (25°C.).

Vapor Pressure—Corresponding to atmosphere of 60% R. H. at 68°F.

Thermal Characteristics—Specific heat 0.54 at 20°C.

Thermal conductivity at 21°C. 12.7 x 10^{-4} cal./cm. sec. °C.

Thermal conductivity at 49°C. 13.6 x 10^{-4} cal./cm. sec. °C.

Sweetening Power—Honey sugars have approximately 25% greater sweetening power than

cane sugar. Hence: 1 gal. average extracted honey (about 9 lbs. 6 oz. total sugars) is equivalent to about 11 lbs. 12 oz. granulated sugar.
1 volume honey is equivalent to about 1.67 volumes granulated sugar.
1 lb. average honey (containing about 17% water) is equivalent to about 0.95 lb. (15.25 oz.) granulated sugar.

TABLE 3. Approximate Equilibrium Points between the Relative Humidity and the Percentage Water Content of Liquid Clover Honey

Percentage Water in Honey	*Equilibrium Relative Humidity*
16.1	52
17.4	58
21.5	66
28.9	76
33.9	81

Lothrop (1937) found honey to be more hygroscopic than invert sirup or corn sirup. Hygroscopicity of honey is a valuable property, however. It aids in keeping honey-containing baked goods and candies fresh and soft, and has been used to prevent excessive drying of tobacco products.

Excessive moisture content of honey can be reduced by exposing it to air of relative humidity lower than its equilibrium value. Killion (1950) has used dehumidifiers to remove over 220 lbs. of water from 130 supers of comb honey in 23 days. A more common way, studied by Stephen (1941), to reduce the relative saturation of the air, is to warm it; forced circulation of hot air will reduce the moisture level of comb honey. Townsend and Burke (1952) have removed 1 to 3 per cent moisture in 24 hours from 72 supers of honey in a 6½- by 7-foot room.

Even when packed in a screw-cap jar, honey can take up moisture if only a simple cardboard insert is present in the cap (Villumstad 1951) Nicol (1937) found none of 22 screw-cap English honey jars to be gastight.

The viscosity of a material is simply its resistance to flow. The beekeeper calls it "body." A heavy-bodied honey has a high viscosity and flows only slowly. Like other physical properties, viscosity of honey depends upon its composition, especially the moisture content. Chataway (1932) proposed the determination of moisture content of honey by a viscosity measurement. She used the time of fall of a steel ball in a special apparatus and claimed an accuracy equal to direct drying.

Oppen and Schuette (1939) have improved Chataway's apparatus for this purpose. Many beekeepers feel that they can get an idea of the moisture content of honey by allowing a bubble to rise in it. This may be quite misleading, since viscosity is quite sensitive to temperature and protein content of honey.

Honey viscosity is of great practical importance to the beekeeper and honey processer. The high viscosity of honey makes it difficult to empty containers and to extract it from the comb. It retards the rate of straining and clarification, including "settling" and clearing of entrapped air bubbles. As all beekeepers know, the body of honey is reduced by heating; the use of some degree of warming greatly facilitates extraction, straining, settling, flow through pipes and emptying of containers. Munro (1943) has shown that heating honey above 86° F. gives no further practical advantage in extraction and handling of most honeys, with the exception of especially heavy honeys of about 14 per cent moisture or lower.

No American honey has to any marked degree the property of *thixotropy,* which is a decrease of viscosity following stirring or agitation which then returns on standing. Heather (Europe) and manuka (New Zealand) honeys are markedly thixotropic. Pryce-Jones (1953) found a protein to be responsible; the property is lost when the protein is removed. Clover honey becomes thixotropic when the heather honey protein is added to it. Pryce-Jones (1953) has written a comprehensive article on the viscosity and related properties of honey.

Mention should perhaps also be made of "spinnbarkeit" which might be termed "stringiness" or "spinnability." Some honeydews and honeys containing honeydew will form long hairlike threads when a rod is dipped into them and pulled away. Ordinary honey does not do this.

The density of a substance is its weight per unit volume. It usually is expressed as pounds per cubic foot, pounds per gallon, or grams per milliliter. The most familiar expression for honey is in pounds per gallon. Honey meeting the grading requirements for U.S. Fancy or Choice must have a density of at least 11 pounds, 12 ounces per gallon.

Specific gravity is the ratio of the weight of a volume of a substance to the weight of the same volume of water. The minimum density noted above for top-grade honey corresponds to a specific gravity of 1.4129. Density and specific gravity may be determined by weighing known volumes, by the use of a hydrometer, or by a specific gravity balance.

These attributes vary with the temperature of measurement and the moisture content of honey, hence temperature must be specified in tables relating moisture content and density, specific gravity, or solids content by hydrometer.

The variation of density of honey with moisture content is sufficiently large that a low moisture honey will tend to layer under a higher moisture honey in a tank unless especial care is taken to mix them. Honey exposed to moist air will absorb water and form a more dilute layer which will remain at the surface for a long time due to its lower density, as shown by Martin (1958). Diffusion of the water through the mass of material is very slow. Table 4 shows how the specific gravity and density of honey vary with its moisture content.

The Brix hydrometer is commonly used for measuring sucrose solutions and is calibrated to read per cent sucrose directly. When used for honey the values obtained are too low by the amounts shown in the table. A honey hydrometer is commercially available.

The refractive index of a substance is actually the ratio of the velocity of light in the substance to that in air. This apparently abstruse and

TABLE 4. The Relationship Between Various Hydrometer Scales and Refractive Index to Moisture Content and Weight per Gallon of Honey*

% Moisture	Sp. Gr. (20°C./20°C.) at 20°C.	°Brix at 20°C.	Diff. between use of honey hydrometer tables and Brix tables in % H_2O	Lb. per Imp. Gal. at 20°C.		Lb. per U. S. Gal. at 20°C.		Ref. Index at 20°C.	% Moisture
				lb.	oz.	lb.	oz.		
13.2	1.4510	85.45	1.35	14	8	12	1	1.5035	13.2
14.0	1.4453	84.61	1.39	14	7	12	0.5	1.5015	14.0
15.4	1.4352	83.13	1.47	14	5.6	11	15	1.4980	15.4
15.8	1.4324	82.71	1.49	14	5	11	14.5	1.4970	15.8
17.0	1.4239	81.45	1.55	14	3.8	11	13.5	1.4940	17.0
17.4	1.4212	81.04	1.56	14	3.2	11	13	1.4930	17.4
18.0	1.4171	80.42	1.58	14	2.6	11	12.5	1.4915	18.0
18.6	1.4129	79.80	1.60	14	2	11	12	1.4900	18.6
19.0	1.4101	79.39	1.61	14	1.4	11	11.5	1.4890	19.0
20.2	1.4020	78.15	1.65	14	0.2	11	10.5	1.4862	20.2
21.0	1.3966	77.33	1.67					1.4844	21.0

*Condensed from more extensive tables by H. D. Chataway (1935) with additions and slight changes. Printer's errors should be checked if the original tables are consulted. The original tables contain temperature corrections for various scales. The method of determination of moisture content by means of a refractometer and the tables have been adopted in Canada, and in the United States by the Association of Official Agricultural Chemists.

difficult measurement provides the simplest and possibly the most accurate method of determining the water content of honey. By use of the refractometer, a relatively simple instrument, moisture in honey can be determined with ease, compared with other methods. Equipment is expensive, however, and because of the small sample required (as little as a drop) care must be taken that the sample is representative. The table relates refractive index to the moisture content of honey. Again the temperature of measurement must be known.

Color is an optical property of honey, inasmuch as it is the result of the different degree of absorption of light of different wave lengths by the constituents of honey. Honeys may vary from virtually colorless to deep red in color through shades of yellow, amber, and brown, with greenish or reddish tinges. A blue honey of unknown origin is produced in North Carolina. Most honeys also fluoresce (emit visible light) in various colors when illuminated by ultraviolet light.

Optical rotation, or rotation of the polarization plane of polarized light, is shown by many types of organic materials. The direction and extent of such rotation differs for various substances. The sugars of normal honey are such that it is levorotatory (left-rotating), while honeydews are sufficiently different in composition that they are largely dextrorotatory (right-rotating). Thus the measurement of optical rotation has been used both to analyze the sugars of honey and to detect the presence of honeydew. More reliable methods are available now for these analyses.

THE COMPOSITION OF HONEY

Moisture Content. The natural moisture of honey in the comb is that remaining from the nectar after ripening. Its concentration is thus a function of the factors involved in ripening, including weather conditions and original moisture of the nectar. The moisture content of honey may change after removal from the hive as a result of storage conditions after extraction. It is one of the most important characteristics of honey, having a profound influence on keeping quality, granulation, and body; yet few beekeepers trouble to measure it, relying instead on rule of thumb (Bauer 1960).

The Sugars of Honey. Since honey is above all a carbohydrate material, with 95 to 99.9 per cent of the solids being sugars, they have been studied for many years. Recently much new information has been published about the sugars found in honey.

Sugars are classified according to the size and complexity of their molecules. The simple sugars *(monosaccharides)* are the building blocks of the more complex types. The dextrose and levulose in honey are examples. The disaccharide sugars are made of two monosaccharides joined in various ways; many of these are known. Common examples are maltose (malt sugar), sucrose (table sugar), and lactose (milk sugar). Other kinds of sugars (higher sugars) are still more complex, being made of three or more simple sugars.

Until the middle of this century, honey was thought to be a simple mixture of dextrose, levulose, sucrose, and an ill-defined carbohydrate material "honey dextrin." Application of powerful new analytical and separation procedures to honey by several groups of investigators in the past twenty years has revealed honey to be a highly complex mixture of sugars; in addition to the long-known dextrose, levulose, and sucrose. Siddiqui (1970) lists in his comprehensive review of the subject maltose, kojibiose, isomaltose, nigerose, $\alpha\beta$ trehalose, gentiobiose, laminaribiose, melezitose, maltotriose, turanose, 1-kestose, panose, maltulose, isomaltotriose, erlose, theanderose, and O-α-D-glucopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→3)-D-glucopyranose as definitely identified. In addition, isopanose, isomaltotetraose, isomaltopentaose, isomaltulose, centose, 1-O-α-D-glucopyranosyl-D-fructose, and O-β-D-glucopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→4)-D-glucopyranose are probably present in honey. No evidence for the presence of often-reported raffinose was found; Siddiqui indicates it was confused with theanderose. Siddiqui's review should be consulted if information is desired on who identified which sugars in honey; research groups in the U. S., Japan, and Canada were responsible.

Many of these sugars probably do not occur in nectar but are formed during ripening and storage by effect of enzyme action and honey acids.

The simple sugars, dextrose and levulose, predominate and give honey its sweetness, hygroscopic properties, energy value, and physical characteristics. In nearly all floral types of honey more levulose than dextrose is present; only very rapidly granulating types such as blue curl, dandelion, and rapeseed have more dextrose than levulose.

Acids of Honey. Because of its great sweetness, the acidity of honey is largely masked. The acids contribute to the honey flavor complex. Until recently it had been thought that citric acid was the predominating honey acid; Nelson and Mottern (1931) isolated and positively identified acetic, butyric, citric, malic, and succinic acids in honey. Other acids reported were formic and acetic.

Recently it was found (Stinson *et al.*, 1960) that the most important acid in honey is gluconic acid, which is derived from dextrose. Other acids identified for the first time in honey, in addition to those listed above, were lactic and pyroglutamic. The inorganic acids, phosphoric and hydrochloric, are also present. Honey contains traces of amino acids, the building blocks of proteins. Komamine (1960) has identified sixteen such acids in honey.

Minerals in Honey. The ash content of honey averages about 0.17 per cent of its weight, but varies widely, from 0.02 to over 1.0 per cent. Schuette and his students examined the composition of honey minerals rather extensively (see Table 5), (Schuette *et al* 1932, 1937, 1938, 1939).

Although the mineral content of honey is not very high, honey added to the diet in place of sugar does increase the mineral intake and thereby adds to the other values for honey.

Calcium and phosphorus are the minerals present in the body in the largest amount; next in order come potassium, sulfur, sodium, chlorine, and magnesium. About 99 per cent of the calcium and 80 to 90 per cent of the phosphorus are in the bones and teeth; the rest is in the soft tissues and body fluids and is highly important to their normal function. Sodium and potassium are similar in chemical properties but differ in their location within the body. Sodium is largely in the fluids circulating outside the cells while potassium is mostly inside the body cells. They are vital in keeping a normal balance of water between the cells and the fluids. They are also essential for nerve response and muscle contraction and, with proteins, phosphates, and carbonates, keep a proper balance between the amount of acid and alkali in the blood. Magnesium is related to calcium and phosphorus in its location and function in the body, with about 70 per cent of the body magnesium in the bones, and the rest in soft tissues and blood, where it has several important roles.

Minerals occurring in very much lower amounts in the body are known as trace elements. Those required for growth of animals include copper, iodine, iron, magnesium, manganese, and zinc. Molybdenum and fluorine are also important. The table lists the amounts of four of these in honey. Iron is vital because it is a constituent of hemoglobin and also

TABLE 5. Mineral Constituents of Honey (Parts per Million)*
(Rearranged from Schuette and co-workers, 1932, 1937, 1938, 1939)

Element	Number of Samples‡	Light Honeys Average	Light Honeys Minimum	Light Honeys Maximum	Dark Honeys Average	Dark Honeys Minimum	Dark Honeys Maximum
Potassium	13, 18	205	100	588	1676	115	4733
Chlorine	10, 13	52	23	75	113	48	201
Sulfur	10, 13	58	36	108	100	56	126
Calcium	14, 21	49	23	68	51	5	266
Sodium	13, 18	18	6	35	76	9	400
Phosphorus	14, 21	35	23	50	47	27	58
Magnesium	14, 21	19	11	56	35	7	126
Silica (SiO_2)	14, 21	22	14	36	36	13	72
Silicon (Si)	10, 10	8.9	7.2	11.7	14	5.4	28.3
Iron	10, 10	2.4	1.2	4.8	9.4	0.7	33.5
Manganese	10, 10	0.30	0.17	0.44	4.09	0.52	9.53
Copper	10, 10	0.29	0.14	0.70	0.56	0.35	1.04

*The parts per million equal the milligrams per kilogram, or divided by 10,000 equal the actual per cent of the total honey composition.

‡The first figure refers to the number of samples of light honeys, while the second figure refers to the number of samples of dark honeys.

of several enzymes which are important in oxidative reactions. Manganese is also most important in many enzyme systems and is the primary metal for the enzymes of the citric-acid cycle, the scheme of metabolism wherein most of the final oxidation to carbon dioxide occurs. The details of the function of copper in humans are obscure. It is thought to be concerned with the oxidation of tyrosine and vitamin C and in the formation of melanin, the skin pigment. It is also involved in many aspects of iron metabolism.

It may be seen from the table that, in general, dark honeys are richer in minerals than light honeys. This was noted by the Wisconsin group, and has been confirmed statistically in a recent survey of American honeys (White, 1961a).

Enzymes in Honey. Enzymes are complex materials formed in living cells that aid in carrying out the myriad reactions and processes of life. In their presence, processes are easily accomplished that man has not learned to duplicate in their absence. The most important enzyme in honey is undoubtedly invertase (also known as saccharase or sucrase) which converts the sucrose of nectar into the "invert sugars," dextrose and levulose, found in honey (*see* "Ripening of Honey"). Another important enzyme (for a different reason) is the diastase (amylase) found in honey. Its origin and function in honey are obscure; it has been stated to arise chiefly from the bee (Ammon, 1949). Its importance lies in its ease of measurement and its instability to heat. Europeans, who prefer their honey essentially unheated, use the diastase level as an index of the heating history of a honey. Occasionally honey shipments are downgraded by German importers as being too low in diastase and hence useful only as commercial honey at a lower price. Some U.S. honeys are naturally low in diastase, but it is claimed this is due to climatic conditions. It is finally being recognized that the diastase content of an unheated honey can deteriorate in storage (White, *et al* 1964; Hadorn and Kovacs, 1960). Half of the diastase content can disappear in 17 months at ordinary temperatures (75 to 80° F.). Other enzymes reported to occur in honey are catalase and phosphatase.

The presence in honey of the enzyme glucose oxidase was reported by White *et al* (1963). This enzyme originates in the pharyngeal gland of the bee and oxidizes glucose to gluconic acid (the most abundant acid in honey) and hydrogen peroxide. The identity of this hydrogen peroxide with inhibine, the antibiotic principle of honey, was proved (see Inhibine). Catalase has unequivocally been identified in honey (Schepartz and Subers, 1966).

Vitamins in Honey. There is no doubt that honey contains small but measurable amounts of several vitamins. Using both chemical methods and bioassays, Haydak *et al.,* (1942) found thiamin, riboflavin, ascorbic acid, pyridoxine, pantothenic acid, and nicotinic acid, in low and extremely variable amounts, which they ascribed to the floral source and pollen content of the honey. They also noted that filtration of honey diminished its vitamin content (Haydak *et al.,* 1943). Kitzes, Schuette, and Elvehjem (1943) assayed 40 samples from various parts of the country and of various ages for the B vitamins (riboflavin, pantothenic acid, thiamin, nicotinic acid, and pyridoxine). Their results for the latter two vitamins were much lower than those of Haydak *et al.* They found variation among samples to be large and also ascribed it to honey source and pollen content.

Viewed in the light of the recommended daily requirements of the various vitamins and the amounts of honey normally consumed, the vitamin content of honey is of little practical significance.

Honey Dextrins. In the earlier methods of analyses of honey, measurement was made of the amount of material thrown out of honey solution by the addition of strong alcohol. This material was called honey dextrin by analogy with similar behavior of starch sirup when mixed with alcohol. Starch dextrins are long-chain compounds of glucose formed by partial breakdown of starch. The so-called honey dextrins have been shown (von Fellenberg and Ruffy, 1933) to be quite different from starch dextrins. The "dextrin" (or "higher sugar") content of honeydew is generally higher than of honey. The higher sugars of honey all contain levulose and can thereby be differentiated from the glucose-containing starch dextrins; in fact, admixture of corn sirup with honey can be detected in this way (White, 1959).

Honey Colloids. Colloids are large molecules or aggregates of smaller molecules that exist in permanent dispersion in a liquid. They do not settle out and are too small to be filtered out by ordinary filtration media. They are intermediate between materials in true solution (sugars in honey) and in suspension (pollen grains, for example). Lothrop and Paine (1931, 1932, 1933), and Paine *et al.,* (1934) have studied honey colloids extensively. They report them to be gummy, noncrystalline substances consisting of proteins, waxes, pentosans, and inorganic constituents. They have examined the influence of colloids on honey properties — foaming, color, and turbidity. Light honeys usually contain around 0.2 per cent colloidal matter while dark honeys may contain nearly 1 per cent.

Recent examination of honey proteins (White & Kushnir, 1967) has shown 4 to 7 protein components to be present, four of which are common to all samples examined and appear to originate from the bee, while the others differ with floral source. Since 35-60% of the total nitrogen content can be removed by dialysis, the protein content of honey cannot be estimated from the nitrogen analysis alone. True protein content was in the range of 0.1-0.6%.

Inhibine, The Antibiotic Activity of Honey. Not the least of the many ancient uses for honey was in medicine as a dressing for wounds and inflammations. Although today medicinal use of honey is largely confined to folk medicine, there are occasional reports in the modern medical literature describing its value in treatment of wounds, burns, infections and other disorders. One property, a definite anti-bacterial effect was reported in 1937 by Dold *et al.* (1937) and called "inhibine." It is measured by the effect of a sample of diluted honey on the growth of bacteria inoculated on a plate, and was found to be heat sensitive. Its identity remained unknown for 25 years until White *et al.* (1963) showed that the inhibine effect was due to hydrogen peroxide produced and accumulated in diluted honey by the enzyme glucose oxidase, during its action on honey glucose to form gluconolactone (which equilibrates with gluconic acid). It is heat sensitive; the amounts vary with floral type and previous processing history of honey. This subject has been reviewed (White, 1966).

Because of the high density and acidity of honey the non-sporeforming organisms that cause human diseases cannot live in it. It was shown some years ago (Sackett 1919) that various pathogenic bacteria were killed when introduced into honey.

Other Biologically Active Materials in Honey. In this category such entities as vitamins and minerals might be included insofar as they possess specific biological activity, i.e. a response by living material to their presence. Over the years honey has been examined for several kinds of biological activity. Such responses as root-promoting activity (Oliver, 1940), amelioration of guinea pig joint stiffness (Church, 1954), estrogenic activity (Dingemanse, 1938), yeast-growth response (Lochhead and Farrell, 1930), cholinergic action (Marquart and Vogg, 1952), and "appetite promotion" (Anon, 1957) have been reported in the scientific and lay literature. Cholinergic activity has been ascribed to the presence of choline and acetylcholine in honey.

Several of these effects were recently studied (Smith *et al.* 1969) in an effort to verify them. Rats fed on diets in which honey replaced sucrose or starch showed greater weight gains; yeast growth stimulation was seen; only marginal effect, if any, on guinea pig joint stiffnesss was found. Several honeys improved rooting of plant cuttings, and none showed any estrogenic activity.

Another type of biological activity is toxicity. A few types of honey are known to contain sufficient amounts of toxic substances derived from their plant source that a greater or lesser degree of discomfort follows their consumption. Fortunately, beekeepers are well aware of these and make special effort to avoid selling honey from such sources as rhododendron, azalea, mountain laurel, the Australian tree tutu, and jessamine. This subject was recently reviewed by White (1973).

AROMA AND FLAVOR OF HONEY

The aroma and flavor of honey are its most important characteristics from the beekeeper's and consumer's point of view, yet relatively little work has been done on them. When beekeeping and processing practices are considered, their effect on flavor is often ignored.

The delightful aroma and flavor of fresh honey are remembered with pleasure by all who experience this. Yet we may at times be disappointed by flavor (and off-flavor) of commercial honeys. There are as many different honey flavors as there are plant nectar sources. Many of these are of only local significance, and usually preferences are expressed for many honey types in their area of production that would not be especially welcome elsewhere. There are of course some kinds of honey that are unpalatable to humans though acceptable to bees as stores. Beekeepers are generally adept at avoiding the inclusion of such honeys in their salable product.

The delicate bouquet and fine flavor of honey are particularly vulnerable to heat and improper storage. In addition to loss of the more volatile aromas, excessive heat can alter honey flavors and introduce off-flavors from the effect of heat on the sugars, acids, and protein materials in honey. Heating can be applied to honey to delay granulation and avoid fermentation without danger of flavor damage if care is given to the duration as well as the amount of heat. Removal of heat after the desired treatment is essential to the best quality product. Flavor loss can also be serious during storage, as explained in more detail under "Storage of Honey."

Recently introduced highly sensitive analytical instruments have been used to identify the specific materials making up the aroma of honey. More than fifty have been identified (Cremer and Riedmann, 1965), illustrating the complexity of honey aroma.

Of the hundreds of nectar-bearing plants which bees visit, relatively few are of commercial importance, though the taste and color characteristics of hundreds have been described (Pellett, 1947; Lovell, 1956). Each honey type has a characteristic flavor and color and can thus be identified. They also are relatively consistent in other characteristics — relative amounts of the various sugars, acids, nitrogen, and ash content. Table 6 shows how the average composition of 74 honey types and 4 honeydews compares with the average of all American honeys. In the table a plus sign means that the honey type is higher than the average in the listed characteristics, a minus sign means that it is lower, and no mark means that it is near the average. An "n" means that insufficient data were available to estimate. These data were obtained in an analytical survey of American honeys (White *et al.,* 1962). In the same work it was shown that area of production has little effect on the composition of honey (Fig. 2) with cotton honey from three states, alfalfa honey from two areas, and orange honey from two states showing relatively little variation in composition (White, 1961b).

Nectar and its Conversion to Honey

It has been said that to know the composition of nectar we need only to examine the components of honey, the only difference being

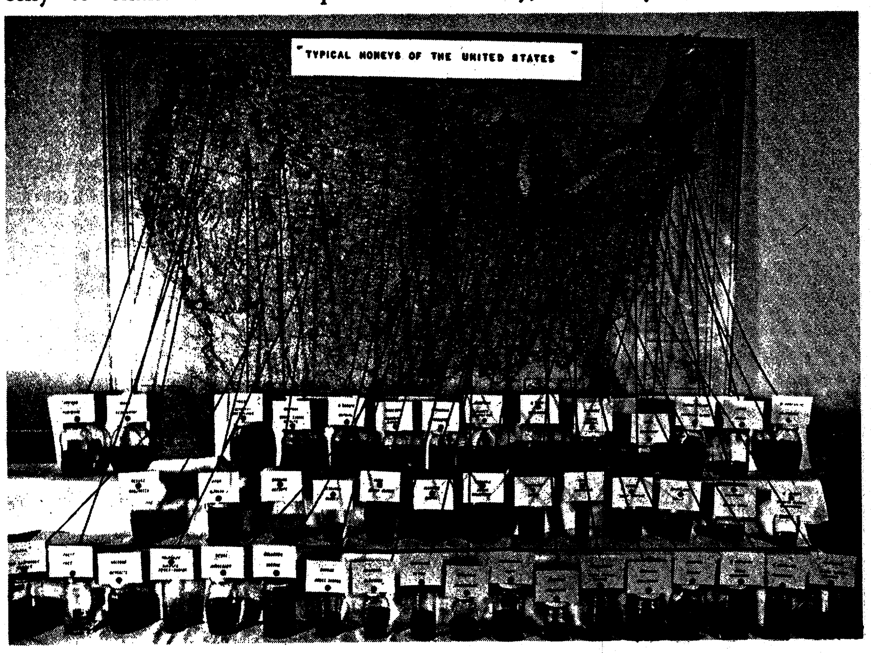

FIGURE 2. This is a display of typical honeys of the United States—a part of the 490 samples collected by Dr. White. *(U.S.D.A. photo by M. C. Audsley)*

TABLE 6. Characterization of Various Floral Types of Honey

	Color	Granulation	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acidity	Lactone	Total Acidity	Lactone/Free Acid	Ash	Nitrogen	Diastase
Alfalfa		+		+	+		−	−					+	−	−	
Aster	+	−			−	+			+		−		−	+		n[1]
Athel Tree	+	+	+	+			−							+	+	n
Bamboo, Japanese			−			+										n
Basswood														−	−	
Bergamot	+		+								+	+				n
Blackberry	+	−		−		+	+		+				−	+		−
Blueberry	+					+			+							n
Blue Curls		+	−	+					−		+					n
Bluevine			−	−												n
Boneset	+		+	−								+			+	
Buckwheat	+		−		+					+		+				+
Canteloupe		+		+							+	+			−	−
Cape vine			−				−								−	
Chinquapin	+	−	−	−		+	+	+	+		−		−			
Clover, crimson	−								−					−	−	
Clover, hubam	−			+			−							−	−	n
Clover, sweet yellow	−		+		+					−		−	+	−	−	n
Coralvine	+	−	−	−			+	+	+	+		+		+	+	n
Cotton		+		+		−	−		+					+		
Cranberry	+	−	−	−			+	+	+					+		
Gallberry		−	+						+						−	
Goldenrod				+	−		−		+		−		−			+
Grape	+	−	−	−		+						+			+	n
Holly	+	−		−		+	+		+							n
Horsemint				+			−		−		+	+	+			
Locust		−	+	−						−		−		−	−	−
Manzanita		+	−	+						−		−			−	n
Marigold				+			−		−		+		+	−		+
Mesquite		+	+	+			−				−				−	n
Mexican clover	+	−								+		+				+
Mint	−			+	+			−							−	
Mountain laurel	−	−	−	−	−	+	+	+	+	−	−	−	−			+
Mustard	+	−		−		+			+					+	+	
Orange									−		+		+	−		n

Characterization of Various Floral Types of Honey—*Continued*

	Color	Granulation	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acidity	Lactone	Total Acidity	Lactone/Free Acid	Ash	Nitrogen	Diastase
Orange-grapefruit					+									−	−	−
Palmetto		−				+			+	−		−			−	−
Palmetto, saw	+										+	+	+	+	−	−
Pepperbush	+		−					+			+			+		−
Peppermint	+		+						+				−	+		n
Peppervine	+	−	−	−		+									−	−
Poison oak		−		−		+	+	+						+	+	n
Privet	+						−		−	+	+	+				n
Prune	+	+	−	−		+	−		+	−	−	−	−	+	+	n
Raspberry	+	−	−	−			+					+		+	+	−
Rhododendron	−	−	−	−		+		+	+	−	−	−			−	+
Sage		−	+	−												n
Snowbrush	+									+		+				+
Sourwood		−		−		+	+		+		−	−			−	
Spanish needle	+	−	+	−							+	+	+	+	+	+
Spearmint			+											+		n
Sumac	+		−	−			+	+	+	+		+	−	+	+	+
Sunflower	+	−						−			+	+			+	−
Thistle, blue	−		−							−		−		−		n
Thistle, star			−		+		+		−		+	+	+			+
Thyme	+								+					+	+	n
Titi	+						−		+	−	−	−	−	+	−	
Titi, spring	+	−	+	−				+	+	−	−	−	−			n
Trefoil	−											−		−	−	−
Tulip tree	+	−	−	−		+	+	+	+	+	−	+	−	+	+	
Tupelo		−	+	−					−		+		+	−		
Alfalfa honeydew	+	+	−							+	−	+	−	+	+	n
Cedar honeydew	+	−	−	−		−	+	+	+	+		+	−	+		n
Hickory honeydew	+	−	−	−	+		+	+	+	+	−	+	−	+		n
Oak honeydew	+	−	−	−		+		+	+	+		+	−	+	+	n

Near average in all above characteristics except diastase, which differs as shown in parentheses: Wild buckwheat (+); clover, alsike; clover, sweet; clover, white; crotalaria (—); cucumber; eucalyptus; fireweed; heartsease (n); palmetto, cabbage; pentstemon (n); purple loosestrife (n); rosinweed (+); vetch; vetch, hairy (—).

1 "n" means insufficient data were available to allow valid comparison.

changes in the water content and inversion of sucrose. This is oversimplification, since it is not clear which of the minor components (enzymes, vitamins, some nitrogen compounds, and acids) may have been added by the bee. Relatively less is known of the composition of nectar because of the difficulty of obtaining sufficient material for examination of the minor components. As long ago as 1886 (Planta, 1886) it was found that nectar contained dextrose and levulose as well as sucrose. Recent quantitative work has shown that though the relative amounts of these three sugars vary widely, they may be relatively constant for a species (Wykes, 1953; Maurizio, 1959; Bailey *et al.,* 1954). The ratios of levulose to dextrose show a much greater variation for nectar than found in honey. Other sugars have been reported in nectar. Wykes (1952) found traces of maltose, melibiose, and raffinose; Taufel and Reiss (1952) reported five unidentified sugars in nectar, and Furgala *et al.* (1958) confirmed the presence of appreciable amounts (1 to 26 per cent of solids) of maltose. The solids content of nectar varies enormously among different plants with extremes of 3 and 76 per cent recorded. The average concentration range in species visited by the honey bee is 20 to 40 per cent; Wykes (1950) and Park (1932) have shown that only a very slight decrease in concentration takes place between the flower and the hive. The solids content increases rapidly in the hive to full honey density.

Aside from this increase in body, the most obvious change is the conversion of nectar sucrose to dextrose and levulose. For many years it has been known that such action ("inversion") does not stop when honey is harvested, but continues slowly during storage if the honey has not been heated. It is brought about by the enzyme invertase added by the bee. With the sucrose inverted, honey can attain a much higher sugar concentration, with higher efficiency in storage and immunity from spoilage by ordinary yeasts and molds.

In a study of the action of yeast invertase on sucrose, English workers noted that the process was not a simple splitting of sucrose to dextrose and levulose but that several more complex sugars appeared during the process to disappear at the conclusion. A similar process was then found (White and Maher, 1953a) to take place when honey invertase acted on sucrose, with different, more complex sugars being formed.

One of these new sugars which was isolated, its structure determined, and named "erlose" by White and Maher (1953b), has been found to be a common constitutent of honey and honeydew (Goldschmidt and Burkert, 1955; Maurizio, 1959). Honey invertase has been shown to differ from other invertases (yeast, mold, and plant invertases) in its action on sucrose.

Thus in the nectar-to-honey transformation, some nectar sugars (dextrose, levulose, and maltose) become more concentrated; sucrose is largely split to dextrose and levulose, and such by-products appear as maltose, isomaltose, erlose and, according to Goldschmidt and Burkert (1955), traces of other complex sugars (kestose, dextrantriose). Another source of the rare sugars in honey may be the action of honey acids on the concentrated simple sugars. In order to trace the source of the rare sugars found in honey, Taufel and Muller (1953) studied the sugars of pollen finding, however, only sucrose, dextrose, and levulose.

Maurizio (1959) has made an exhaustive study of the sugars of various nectars and the corresponding honeys. She points out that the sugar "spectrum" of a honey depends on the sugars present in the nectar and the influence of enzymes of the bee and of the nectar. She has classified various nectars and honeys on the basis of the dextrose-levulose ratio and the relative levels of sucrose and monosaccharides.

Relatively little is known of the origin of other honey constitutents such as the acids and vitamins. Komamine (1960) has suggested that a part of the amino acids of honey originate from pollen. Probably the bee adds diastase, since sugar-fed honey shows diastatic activity, but some may arise from pollen, as a correlation between these factors has been shown (Vansell and Freeborn, 1929).

It may appear that at least some of the vitamin content of honey may be associated with pollen, since filtration has been reported to lower the content of several vitamins (Haydak *et al.*, 1943).

Granulation of Honey

A supersaturated solution is one that contains more dissolved material than can normally remain in solution. Such solutions are more or less unstable and in time will return to the stable saturated condition with the excessive material coming out of solution. Many honeys are in this category with respect to their dextrose content and will equilibrate by crystallizing the excessive dextrose out of solution. Crystallizing tendency is related to honey composition and storage conditions; some honeys never crystallize while others will do so within a few days of extraction, or even in the comb (Fig. 3).

Granulation is characterized by firmness and by the fineness of the crystals or grain. A fine-grained crystallization is characteristic of an unheated honey, or one that has been "seeded" either naturally or intentionally with fine-grained honey. Such semi-solid honey, sold under various trade names, is of a fine nongrainy, nonrunning texture that facilitates its use at the table. It is susceptible to breakdown or softening of texture when stored at temperatures higher than 80 to 85° F., and also can soften and partly liquefy due to natural changes at lower temperature (*see* "Storage of Honey").

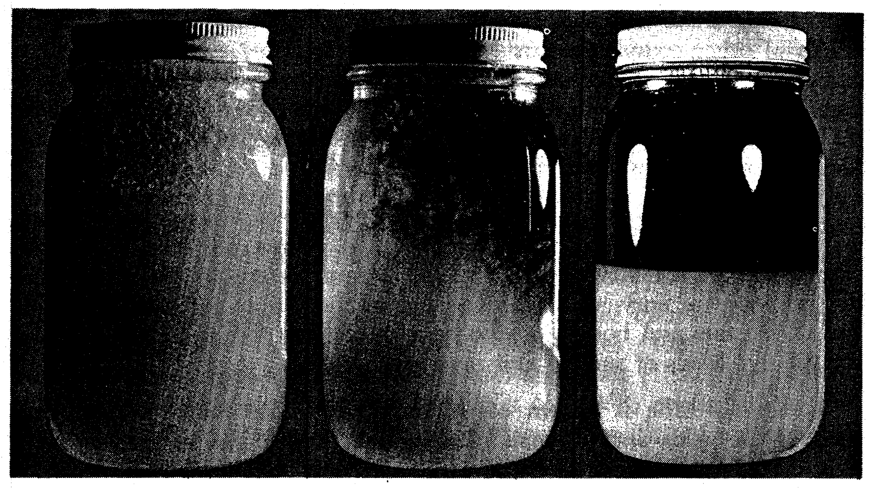

FIGURE 3. The jar of honey at left has granulated completely. The bubblelike formation toward the top of the jar is the result of fermentation after granulation. The jar in the center represents partial granulation with coarse crystals in the upper half and the lower part solidly granulated. The jar of honey at right shows natural partial liquefaction after complete granulation. Eventually, the sample may completely liquefy.

When honey granulates slowly, either because of its composition or because natural "seed" crystals have been destroyed by heat, the size of crystals is much larger; such a product is of reduced commercial value. Careful heating will redissolve such crystals; the coarser they are, generally, the more difficult they are to redissolve (*see* "Processing and Storage of Honey").

Several attempts have been made to express the liability of a honey to granulate. The ratio of levulose to dextrose has been most used. White (1961c) has shown that the dextrose-to-water ratio first applied by Austin (1958) is more closely related to the granulation tendency of honey than other indices are. D/W ratios of 1.70 or lower appear to be associated with nongranulating honey, and values of 2.10 and higher predict rapid completion of granulation.

Table 6, "Characterization of Various Floral Types of Honey," shows the granulating tendency of many honeys insofar as it deviates from the average. Honeys marked "minus" in the column under "granulation" are substantially nongranulating and those marked "plus" granulate rapidly. Even though a honey may be a granulating type, it can be maintained in the liquid state for considerable time. If the so-called "crystal nuclei" (very fine crystals of dextrose, dust particles, or possibly pollen grains) are eliminated and the honey is protected from subsequent contamination and storage temperatures favoring crystallization (50 to 60° F.) are avoided, honey will remain liquid for many months.

The most favorable temperature for honey granulation is 57° F., with both higher and lower temperatures being less effective. Storage of honey at very low temperatures (0° F. or lower) greatly retards but does not eliminate granulation, probably because the extremely high viscosity reduces the diffusion necessary to the increase of crystal size. Granulation does not take place at these temperatures. According to de Boer (1932), the most effective temperature for *initiation* of crystallization is lower, around 5 to 7° C. (41 to 45° F.); fluctuating temperatures in these ranges are particularly effective in promoting granulation.

Since the U.S. retail honey market largely favors liquid honey, some types of processing is necessary to maintain the liquid state, as many honey types will normally granulate, though some will not. This is most commonly done by straining, heating, or filtration. Heating must be done without damage to flavor or color. The most-used heating conditions appear to be 30 minutes at 140 to 150° F. In general, lower temperatures, even for much longer times, will not be effective. Higher temperatures may be used providing the time is sufficiently short and means are included for rapidly reducing honey temperature to 130° or less. Austin (1953) recommended 170° for 5 minutes with rapid cooling.

After a honey is processed for destruction of crystals and nuclei, care must be taken to avoid re-contamination with dextrose crystals. Dextrose crystals, like yeasts, may actually float in the air in the honey house. Utensils, storage tanks, and pipelines may contain crystals.

Small crystals may be present in honey and induce granulation without being perceptible to the unaided eye. A useful device in examining

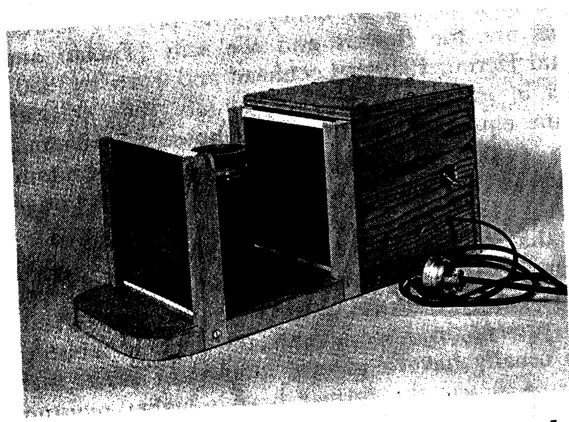

FIGURE 4. This simple polariscope is a great aid in judging honey. *(U.S.D.A. photo by M. C. Audsley)*

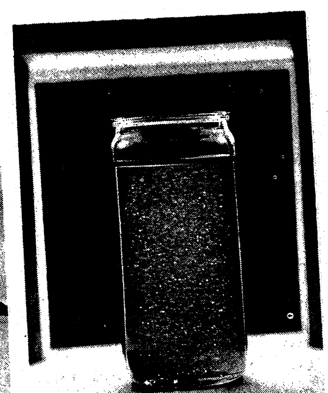

FIGURE 5. Cleanlinesss and crvstallization in honey are readily observed by the light. *(U.S.D.A. photo by M. C. Audsley)*

honey for crystal traces (White and Maher, 1951) is shown in Figure 4. This simple polariscope can easily demonstrate the presence of less than 0.004 per cent of fine-grained crystallized honey mixed with liquid honey. In fact, by appearing as a light object on a dark background, a single crystal is large enough to be visible (Fig. 5).

Fermentation of Honey

Fermentation of honey is caused by the action of sugar-tolerant yeasts upon levulose and dextrose, resulting in the formation of alcohol and carbon dioxide. The alcohol in the presence of oxygen then may be broken down into acetic acid and water. As a result, honey that has fermented may have a sour taste. Due to the release of the carbon dioxide gas, fermenting granulated honey will show a lightened color, whitish streaks, or mottling, and if liquefied it will exhibit considerable foaming, particularly during heating. Upon standing, such granulated honey will partially liquefy, eventually forming an upper liquid mass capped by a foamy layer.

Fermentation of honey is often called "honey spoilage." Compared with other yeast fermentations it is relatively slow. The degree of spoilage or effect upon flavor and quality depends upon the length of time fermentation is allowed to proceed before being stopped by heating or other treatment. Most honey spoilage by fermentation results after granulation. Since the greater proportion of honeys granulate after extraction and thereby become liable to fermentation, all honey producers and bottlers should be thoroughly acquainted with the factors affecting granulation and fermentation. Necessary steps should be taken to prevent spoilage by fermentation of any honey placed in storage.

Ordinary yeasts do not cause fermentation of honey because they cannot grow in the higher sugar concentration. Spoilage by bacteria is not possible because of the high acidity of honey. The primary sources of the sugar-tolerant yeasts are the flowers and the soils (Fabian and Quinet, 1928; Lochhead and Heron, 1929). Lochhead and Farrell (1930) have shown that the soils in established apiaries contain sugar-tolerant yeasts, while the air and the equipment in the honey house are contaminated with them. Similarly, combs in the hive, particularly those containing honey from the previous season, and wet extracting combs in storage, may be abundant sources of yeasts.

It should be assumed that all honeys contain yeasts when planning for their care. The number of yeasts in various honeys will vary between rather wide limits, from one in 10 grams to 100,000 per gram; the greatest number usually being present in honeys with the highest moisture content. Uncapped combs usually have a greater number of yeasts than capped combs from the same super, the former having higher moisture content due to incomplete ripening or to absorption of moisture.

The chief factors in honey fermentation are yeast and moisture content. Interrelated with these are the storage conditions and presence of granulation. Lochhead (1933) has pointed out that the honeys with less than 17.1 per cent water will not ferment in a year, no matter what the yeast count may be. If the moisture content lies between 17.1 and 18 per cent, honey with a yeast count of 1000 per gram or less will be safe from fermentation for a year; between 18.1 and 19 per cent moisture, a count must be only 10 per gram to assure a honey keeping for a year. Above this moisture level, more than one yeast spore per gram means an active danger of fermentation. Granulation of honey always increases the liability of fermentation because of the appreciable increase in the moisture content of the remaining liquid portion. Most honey that ferments does so after granulation. According to Wilson and Marvin (1932), honey yeasts will not grow below 52° F., hence storage at 50° F. or below should protect honey from fermentation. Temperatures of 52 to 60° should be avoided because they encourage granulation. Storage at higher temperatures (100° F.) would also prevent fermentation but honey is damaged by storage at such elevated temperatures.

If honey is heated at 145° F. for 30 minutes it will be safe from fermentation if protected from further yeast contamination. Townsend (1939) has found that the vegetative forms of five honey yeasts common in Canada are destroyed in honey of 18.6 per cent moisture by the time-temperature conditions shown below.

TABLE 7. Conditions Required to Kill Yeasts in Honey*

Time at Indicated Temperature	*Temperature*
470 min.	125°F.
170	130
60	135
22	140
7.5	145
2.8**	150
1.0**	155

*Calculated from data of Townsend (1939). "Come-up" time not included.
**Extrapolated from logarithmic curve constructed from Townsend's data.

Where unheated honey is stored in bulk overwinter, it may be relatively safe during cold weather but is most liable to spoil in the spring or if shipped to a warmer storage place during the winter.

To summarize:

1. All honey should be considered to contain yeasts.
2. Honey is more liable to fermentation after granulation.
3. Honey of over 17 per cent moisture may and over 19 per cent will ferment.
4. Storage below 50° F. will prevent fermentation during such storage but not later.
5. Heating to 145° F. for 30 minutes, or equivalent, will destroy honey yeasts and thus prevent fermentation.

Processing and Storage of Honey

The flavor and desirability of well-ripened honey are at their peak in the comb. Man's efforts to convert it to his use must inevitably result in some deterioration, but whether it is significant depends on the treatment received in the hands of the beekeeper and subsequent handlers. The best processing is the least processing that will meet the objectives. While "raw" honey will always have its devotees, today's retail markets require a honey that will not ferment — one that will remain liquid and have an attractive appearance. These objectives are sometimes met at the expense of honey's most valuable asset, flavor, but with proper methods can be attained with preservation of the original full flavor and aroma.

Heat is the only practical agency for preventing granulation and fermentation but it is a cause of deterioration of honey quality. Application of heat by the so-called "flash" method, a continuous process in which a honey is heated very rapidly in small quantity in a closed system, strained or filtered and then rapidly cooled, probably represents the least heat exposure that will accomplish the desired ends. Treatment in a closed system minimizes losses of volatile aroma during the heating period, and cooling minimizes heat-induced flavor and color changes and allows a higher heat to be used for a shorter time. Townsend and Adie (1956) have described equipment that will heat and cool 300 or 600 lbs. of honey per hour, either for a liquid or granulated honey pack. Honey must have a preliminary straining before being heated so that off-odors or flavors will not be imparted by the action of hot honey on the extraneous material.

With honey becoming less of a seasonal commodity since modern merchandising requires year-round availability, the proper storage of honey grows more important. Honey for export may be stored before or after shipping, or both, and unfavorable storage conditions can bring about enough lowering of honey quality to cause considerable confusion between buyer and seller. Honey stored under government loan may deteriorate seriously in color. The changes that take place in honey during storage have only recently been examined in detail. It has long been known that honey darkens with age and Milum (1948) has shown that heat processing does not increase the later darkening of honey. His data demonstrate the dependence of honey darkening upon temperature of storage.

De Boer (1934) noted that the changes which are brought about in honey by heating also occur during long storage of honey. He specifically referred to the production of hydroxymethylfurfural, a degredation product of honey sugars, and a weakening of honey enzymes. He did not agree with earlier investigators that the ratio of fructose to dextrose decreased. It has recently been found (White, Riethof, and Kushnir, 1961) that during storage of honey at ordinary temperature (76° F. ±3°) about 9 per cent of the simple sugars are converted into more complex forms, with twice as much dextrose disappearing as levulose. Thus the ratio of levulose to dextrose does increase considerably. Acidity of some honey increases in storage, and half of the diastase in a honey will be lost after 17 months of such storage. Thus an unheated honey can be naturally low in diastase if it has been stored for an appreciable time.

All of these deteriorative changes can be avoided by storing honey at low temperatures. For this purpose temperatures should be below 50° F. for unheated honey though great advantage will result from avoiding temperatures over 60° F. In fact, honey kept at very low temperatures for years cannot be distinguished in properties, flavor, color, and aroma from the season's freshest product. It must be remembered, however, that the 50 to 60° interval is particularly dangerous for unheated honey from the fermentation viewpoint. Storage temperatures in the 80's and particularly the 90's, even for relatively short times, must be avoided for a quality product. Deterioration in color, flavor, and enzyme content is particularly rapid in this range.

Preparation of Honey for Market. This is the title of a comprehensive bulletin by Townsend (1961). Detailed procedures and diagrams are given describing the removal of moisture from honey before extraction (with details on hot rooms), uncapping, and straining, including details on the O.A.C. and a modified strainer, as well as the O.A.C. pressure strainer. Small-scale extraction and straining also are described.

For melting honey for repacking, Townsend describes a cabinet that will melt ten cans of honey overnight in which the honey does not exceed 135° F. A procedure for packing liquid honey and finely granulated honey is given in detail. Processing equipment such as a continuous-flow mixer for honey spread, a continuous-flow, high-temperature short-time pasturizer, including cooling for 300 or 600 lbs. of honey per hour, is also described. When remelting coarsely granulated honey in inverted 60-lb. cans, difficulty can arise through the flowing away of the more liquid part before the coarse dextrose crystals can redissolve. This can result in a substantial fraction of the contents remaining unmelted, as a crude dextrose hydrate in the can. Several such occurrences have been described (White, 1958).

EXHIBITION OF HONEY

Honey shows are becoming increasingly popular as a means of reminding the public of the goodness of honey. These exhibitions serve as a potential means of improving honey quality by demonstrating the possibilities of careful handling, and in providing a common ground of competition where the hobbyist can meet the larger producer on even terms.

Showing honey is not difficult but it does require a high level of care and attention to detail. All instructions for entries must be followed to the letter. For liquid honey, careful settling and straining are required, as judges note even the presence of a single bubble on the surface of the honey. Caps must be clean inside and out and jars should be selected

HONEY JUDGING SCORE SHEET

Extracted Honey

1. Degree of density	20 points
a. All entries with water content above 18.6 per cent disqualified	
2. Freedom from crystals	10 "
3. Degree of cleanliness and freedom from foam (clarity)	30 "
4. Cleanliness and neatness of containers	10 "
5. Flavor	30 "
a. Absence of: off-flavor, overheating, and fermentation	
	100 points

Comb Honey and Bulk Honey Frame

1. Uniformity of appearance	20 points
2. Absence of uncapped cells	10 "
3. Uniformity of color	15 "
4. Absence of watery cappings	10 "
5. Cleanliness of section and frame	15 "
6. Freedom from granulation and pollen	5 "
7. Uniformity of weight	15 "
8. Total weight of entry	10 "
	100 points

Finely Granulated Honey

1. Fineness of crystals	35 points
2. Degree of uniformity and firmness	25 "
3. Degree of cleanliness and freedom from foam	15 "
4. Flavor	25 "
a. Absence of: off-flavor, overheating, and fermentation	
	100 points

Chunk Honey

1. Neatness of cut	20 points
Ragged edges, parallel cuts, four-sided cut, and uniformity of size of cut	
2. Absence of watery cappings, uncapped cells, and pollen cells	20 "
3. Cleanliness of product	20 "
a. No travel stain, specks of foreign matter, flakes of wax, foam and crystallization	
4. Uniformity of appearance	30 "
a. Uniformity of capping structure, color, and thickness of comb	
5. Density and flavor of liquid part	10 "
	100 points

for uniformity and uniformly filled. Dust and fine crystals, not easily visible to the unaided eye, may be easily visualized by a judge using the polariscope described in this chapter. Body or moisture content is important; ordinarily there is a maximum moisture value beyond which an entry is disqualified, with additional credit being awarded for lower moisture content to a full count of points for moisture at some lower value.

Flavor is an important attribute, with judgment being similar to that of the U.S. Grades.

In judging finely granulated honey, the texture is probably the most important factor. Absence of grittiness, solidified foam and extraneous material on the surface is highly important. The honey must be neither too hard to spread nor so soft that it runs from the knife, and flavor is as important as with liquid honey. Moisture judgment is not made, since texture and firmness fix the limits.

The score sheet shown here is that of The Eastern Apicultural Society and will provide an idea of the weight given to the various factors by the judges.

The Utilization of Honey

Honey is primarily a high-energy carbohydrate food. The amount of honey used for food far outweighs any of the miscellaneous non-food

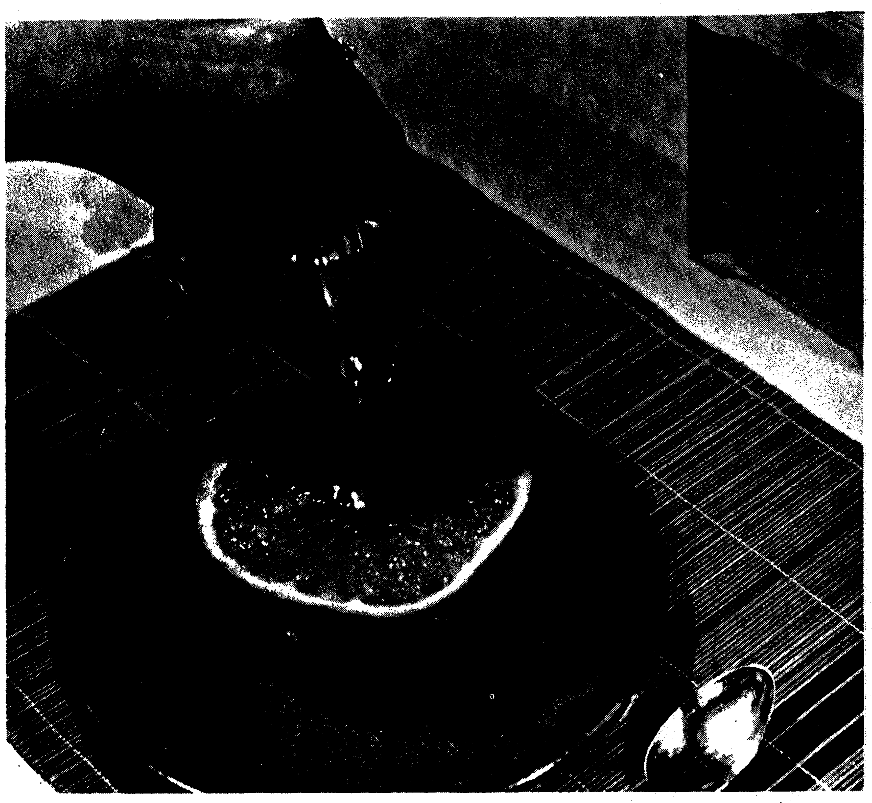

FIGURE 6. Mild-flavored honey drizzled on grapefruit is an ideal sweetener and detracts from the tartness. Honey also is an ideal sweetener for berries and peaches. ***(U.S.D.A. photo)***

uses that have been described in the technical and popular literature. Probably more honey is used directly at the table, than in any other food use (Fig. 6).

Carbohydrates provide most of the energy we need to live and act, though there is no definite nutritional requirement for them. People and animals can survive without them because the body can use fats and protein for this purpose. In general, carbohydrates in our diets may be complex polysaccharides such as starch, with is said to be nutritionally the most important carbohydrate. Only two disaccharide-type sugars (*see* "The Sugars of Honey") are of nutritional importance, sucrose (cane or beet sugar) and lactose, which makes up about 40 per cent of the solids of milk. The monosaccharides, the building blocks of the more complex carbohydrates, also occur in the free form; dextrose and levulose are found in honey and fruits.

Before they can be used by the body, all carbohydrates except monosaccharides must be hydrolyzed or digested into their simple sugar components. These monosaccharides are absorbed into the bloodstream from the intestine, with dextrose entering the bloodstream directly. Galactose (from milk sugar) and levulose are thought to be at least partly converted to dextrose as they pass through the intestinal wall.

The energy from carbohydrates becomes available to the body when dextrose is broken down in the tissues. It is similar to burning, with the great difference that oxidation in the tissues is slower and stepwise. It has been said to be in many ways like a reversal of photosynthesis, the process by which the carbohydrates are made by plants.

Thus we see that honey in providing dextrose and levulose; the latter in higher amounts, is an energy source *par excellence* in which the sugars are ready for assimilation immediately on reaching the intestine. The substantial proportion of dextrose can enter the bloodstream directly, while the fructose provides a slower acting reserve since it must ultimately be converted to dextrose before use.

HONEY IN COOKING AND BAKING

"If you a cook of note would be,
Use honey in your recipe."
Harriett M. Grace (1947)

This subject is one that includes a world of information and countless recipes which have appeared in the bee journals and in cookbooks. The American Honey Institute serves as a source for dissemination of such materials and the reader is referred to its publications, as well as to the bulletins and circulars issued by the home economics staffs of the various colleges and experimental stations.

Honey not only adds flavor in baking, but it has the distinct advantage that the final product, although seemingly dry upon coming from the oven, soon acquires a moist texture and remains palatable, without drying, over a longer period than similar products in which cane sugar is used as the sweetening agent. This quality is due to the ability of the levulose portion of the honey to absorb and hold moisture.

Every honey producer knows countless ways in which honey may be used in menus. The following are just a few suggestions: honey iced tea, honey fruitcake, honey fudge, honey oatmeal cookies, honey-glazed baked ham, honey French dressing, and hot honey lemonade (Fig. 7).

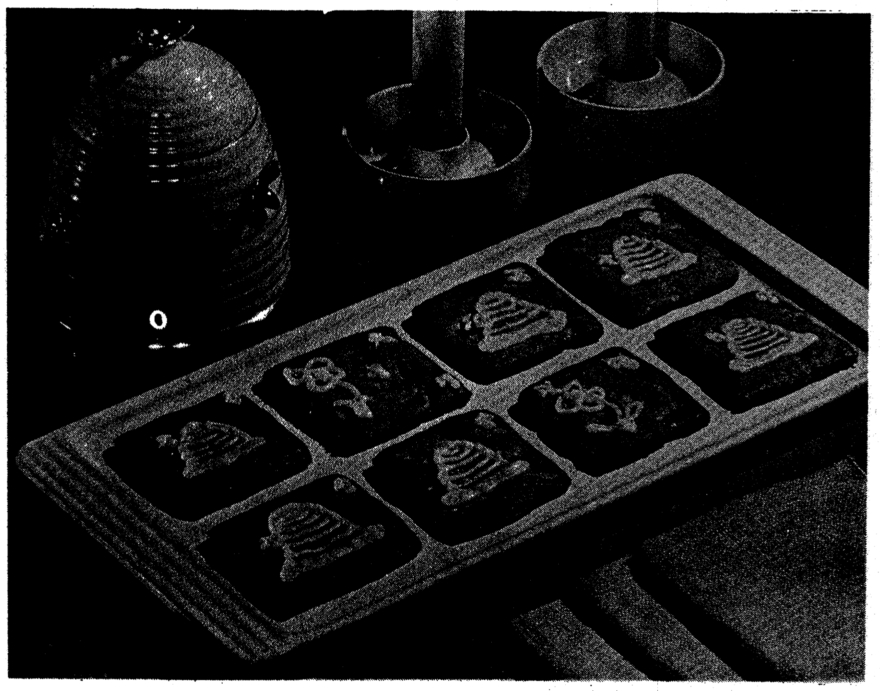

FIGURE 7. Beehive cookies attractively decorated with skeps and floral designs make an inviting display along with the skep of honey and beeswax candles. *(Photo courtesy of The American Honey Institute)*

While tested recipes using honey are to be recommended, honey may be substituted as the sweetening agent where any recipe calls for sugar. In muffins, bread, and rolls, calling for a small amount of sugar, honey can replace the sugar measure for measure without any other adjustment. For cakes and cookies, which require a large amount of sugar, honey can be used measure for measure but the amount of liquid must be reduced one-fourth cup for each cup of honey used, or in the same proportion for fractions of a cup. Moderate oven temperatures, 350° to 375° F., are suggested to prevent the product from becoming too brown.

Commercial bakers have been thought to be the largest users of honey in the food industry. There is a place for honey in the largest bakery as well as the retail bakery on the corner. Though much honey is now used, the industry is so large that even a modest increase would greatly benefit the beekeepers' markets. The larger bakers (as well as other segments of the food industry) may hesitate to use honey because they fear the effects of the natural variability of honey (flavor, color, and moisture content) on their production schedules and product quality. Studies on the role of honey in commercial baking (Johnson, *et al.,* 1957) carried out at Kansas State University have shown that definite advantages in flavor, keeping quality, texture, and "eating quality" arise from judicious use of honey in many types of baked goods, including breads, yeast-raised sweet goods, cakes, fruitcakes, cookies, and pies of several types. Of all the variable characteristics in honey, bakers need be careful only of flavor and color, the latter only in light-colored cakes and white bread (Fig. 8).

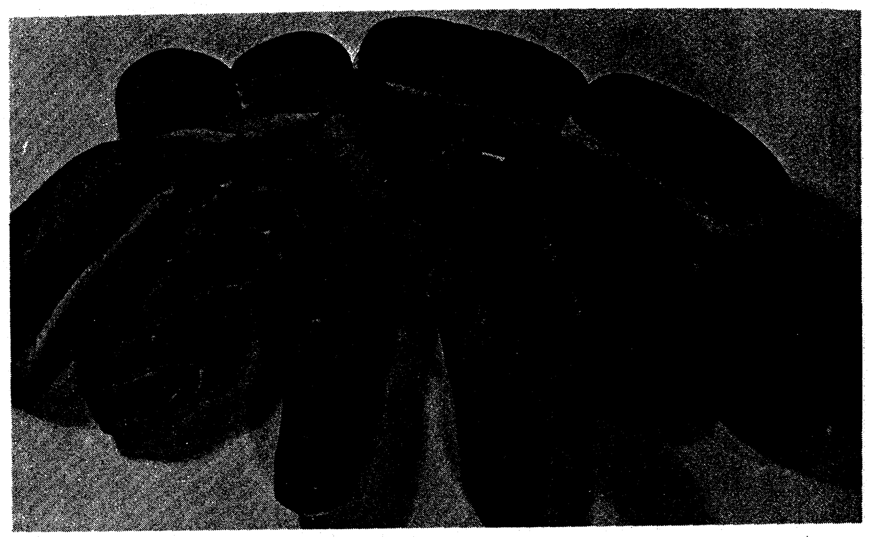

FIGURE 8. Breads from many lands made with honey. Honey adds flavor, keeping quality, texture, and better "eating quality" to many bakery products. *(Photo courtesy of Dr. John A. Johnson)*

Although candies made with honey are among the most delectable, commercial use of honey in confectionery is limited. Relatively little research is done by the candy industry; rather they depend upon their suppliers for this service. Here, as in pharmacy, the use of honey has declined over the years. The candymaking characteristics of honey (high monosaccharide content, especially levulose) limit the amounts that can be used in many formulas, while high temperatures in candy-making are quite destructive to honey flavor and color. Here a new product, a dried honey (Turkot *et al.,* 1960), may be of value since it is effectively a low moisture (1 per cent) hard candy made without damage to flavor or color. Such a product could be useful in prepared baking mixes also.

Honey is an optional ingredient under the Federal Standards of Identity for fruit jellies, jams, and preserves. A prune juice "mellowed" with honey has a good market; in fact honey is the only sweetening agent that may be added to prune juice under the Standards of Identity. An important use for honey is in cereal coatings; a peanut butter enjoying a wide market has honey on the list of ingredients.

HONEY IN INFANT AND CHILD FEEDING

Honey has been used widely in infant feeding with success. Many controlled experiments have given conclusive evidence of its value in correcting various deficiencies in infants and older children. Dr. Paul Luttinger (1922), a pediatrist and pathologist of the Bronx Hospital, New York, recommended the use of honey in any condition of the intestinal tract where the assimilation of starch or the disaccharides is delayed and where prompt absorption is desired. He preferred honey to alcohol, especially in bronchopneumonia, and used it in cases of summer diarrhea in the proportion of 1 teaspoon of honey to 8 ounces of barley water.

Dr. Luttinger highly recommended the use of honey in infant feeding because it does not produce acidosis, its rapid absorption prevents it from undergoing alcoholic fermentation, its free acids favor the absorption of fats, it complements the iron deficiency in human and cow's milk, it increases appetite and peristalsis, and it has a soothing effect which reduces fretfulness.

Some of these attributes of honey seem to have been verified by subsequent investigators. Dr. Paula Emerich (1923) found that anemic children had a greater increase in hemoglobin content of blood when receiving honey and milk than when milk only was added to the normal diet. Weight gains were somewhat lower in the honey group. Haydak and associates (1942) concluded that "dark honey can play a role in prevention and cure of nutritional anemia in rats, while light honey is less effective as a source of the blood-forming elements."

Numerous observers, including Rolleder (1934), Muniagurria (1931), Lahdensuu (1931), Stancanelli (1933), and Farioli (1936), in tests using honey in feeding children of various ages, found special values for honey as compared to other sugars. Included in the observed benefits were an increase in the hemoglobin content of the blood, relief from constipation, better weight gains, a decrease of diarrhea and vomiting, more rapid increase in blood sugars than after sucrose administration, better weight gains when honey was substituted for dextromaltose after faulty nutrition, and good honey tolerance with infants suffering from rickets, inflammation of the intestine, malnourishment and prematurity.

Schlutz and his associates of the University of Chicago (1938) in tests of 11 children found that with the exception of glucose, honey was absorbed most quickly of various sugars in the first 15 minutes following ingestion, yet it did not flood the bloodstream with exogenous sugars until the fasting level was again reached. They concluded that honey should have a wider use in infant feeding.

Dr. Knott and her associates (1941) in a study of 14 healthy male infants for the first 6 months of their lives found better calcium retention with honey than with corn sirup. However, as other factors favoring calcium retention were made more favorable, honey had less effect because each infant has an upper level of responses which is optional for the storage of calcium. Their general conclusion was that honey deserves a wider use in infant dietaries.

More recent work in this field is that of Vignec and Julia (1954) who compared honey with a dextrin-containing maltose preparation and with corn sirup as a formula supplement, using 387 infants. Honey was found superior to corn sirup with respect to average weekly weight gain, linear growth measure, and hemoglobin values. It was not superior to the other carbohydrate in these respects but less gastroenteritis and physiological anemia developed in the honey group. They noted that most infants responded avidly to the honey formulas; this was found useful in managing prematures. They concluded that honey has a definite place in infant feeding.

With this amount of definite evidence in the case of infants and children there seem to be plenty of reasons for including honey, not only in the diets of infants and children, but in the diets of adults as well, and particularly those who are undergoing vigorous exercise under exacting conditions. Formulas which give beneficial results in infant feeding may be found in the references cited.

HONEY FOR ATHLETICS AND STRENUOUS OCCUPATIONS

Honey has been used with beneficial results by athletes in football, basketball, track including marathon running, swimming, wrestling, and 6-day bicycle racing. It has been used as a source of energy in climbing Mt. Rainer, in crossing the Grand Canyon, and in the conquest of Mt. Everest by Sir Edmund Hillary. Honey was used before and during the attempts of deep-sea divers to recover the gold of the sunken Lusitania.

Honey, as explained elsewhere, is readily assimilated, giving athletes a quick source of energy and enabling them to recuperate rapidly from severe exertion with less evidence of fatigue. The latter is particularly true when taken soon after an athletic event. Honey may be used either alone or diluted with orange juice. Siddiqui (1970) has also discussed this use of honey.

HONEY AND DIABETES

One may sometimes note in the beekeeping press that honey may be used by diabetics with no ill effects. This is nonsense, since honey does contain a good proportion of dextrose, the sugar that diabetics cannot handle. Certainly, however, the dietary of the stabilized diabetic could include honey on the basis of its composition as compared with cane or beet sugar. Honey averages 31 per cent dextrose, and tupelo honey around 25 per cent. About 38 per cent of the average honey is levulose. Sucrose content averages about 1.3 per cent. Cane sugar yields in effect (after hydrolysis in the intestine) 52.5 per cent of each sugar. On a weight basis, honey is approximately as sweet as granulated sugar; hence more sweetening power might be considered available to the diabetic at a lower dextrose "price" from honey than from granulated sugar. Any substituting of honey into the diet of the diabetic should be under the direction of a physician.

SUGARS IN THE DIET

Older views of the function of carbohydrates in the diet were that they were solely sources of energy at the rate of 4 calories per gram. The only differentiation was in their availability to the organism. A tremendous amount of research has been done on the proteins and amino acids in nutrition, less on the fats, and possibly less on the sugars. The interrelationship among all of these classes is being examined. "Increasing numbers of nutritionists, experimental and clinical alike, have for some time now discarded the once-current but unfortunate concept of dietary carbohydrates as only supplying caloric needs (so-called empty calories). Evidence is now abundantly at hand to indicate that the kind of carbohydrate may have profound influences on protein and lipid metabolism in both health and disease" (Anon, 1960a). An increasing amount of research is being done on the various aspects of carbohydrate digestion, absorption, and metabolism.

According to a recent statement (Anon, 1960b), "increasing attention will have to be paid to differences between the sugars by all concerned with food and nutrition." Albanese et al. (1968) pointed out that the utilization of dextrose decreases markedly with age, while that of levulose is only slightly affected. Their results suggested that levulose or levulose-containing products are sugars of choice for the aged in that they may provide a ready source of energy and an optimal protein-sparing effect. Thus the preference of many of our senior citizens for honey appears to have a solid foundation in nutritional science. Honey is useful in managing premature infants, a source of strength and energy for athletes and active people, and a most valuable protein-sparing carbohydrate for older people, thereby serving man through his entire lifetime.

MEDICAL USES OF HONEY

A considerable medical literature (largely European) exists on the use in various disorders of honey, honey derivatives, and combinations of honey with various drugs. A number of instances of successful treatment of severe burns with honey appear in the beekeeping literature. Its high sugar content, minerals, and antibacterial action are believed responsible for its value as a surgical dressing by Bulman (1955) and Seymour and West (1951), explaining a honey use known to the ancient Egyptians and popular in the Middle Ages. Blomfield (1973) has reported honey dressings to surpass any other local applications for treatment of decubitus ulcer and recommended it as a valuable and inexpensive cleansing and healing agent for surface wounds.

Although honey was at one time widely used in pharmacy it was displaced long ago. Recently it was shown (Rubin *et al.,* 1959) that honey can be used successfully as a vehicle, sweetening and flavoring a number of medicinal preparations. Stable palatable formulations of ferrous sulfate, triple sulfa, and terpin hydrate were made, as well as several effective cough preparations. Formulations containing the vitamins riboflavin and thiamine as well as riboflavin alone are sufficiently stable for commercial use.

HONEY WINE

Strictly speaking, wines are made from grapes; those made from honey are more properly "meads." They were possibly man's earliest alcoholic drinks, being known in India thousands of years ago, and the history of mead, like that of honey, can be traced through five thousand years. Classic meads may be blended with herbs; many types are recorded, such as sack mead, metheglin, sack metheglin, bochet, cyser, pyment, hippocras, and melomel.

Generally mead is not commercially available, but many beekeepers and others find it of interest to make their own. An extensive annotated bibliography is available (Morse, 1958) from Cornell University. Four simple recipes have been published by Morse (1954). More detailed instructions are available (Dennis, 1957).

Honeydew

This is a sweet liquid excreted by Hemipterous insects, principally plant lice (aphids) and scale insects, feeding on plants. It is frequently gathered and stored by bees and is generally considered inferior to honey in flavor and quality. It may often be found on leaves of such trees as oak, beech, poplar, ash, elm, hickory, maple, tulip, willow, linden, and fruit trees as well as fir, cedar, and spruce. The amount of honeydew collected will depend on the availability of nectar, which is generally preferred by the bees.

An average composition of honeydew is given later (White, 1960). It is based on 14 samples from the 1956 and 1957 crops, including alfalfa, cedar, hickory, oak, and several unidentified types.

Comparison of these values with those given for honey shows honeydew to be lower in levulose and dextrose, darker in color, and higher in

, higher sugars, acidity, ash, and nitrogen. These differences have n noted by others; in fact Kirkwood *et al.* (1960) have proposed a . in which a calculation is made relating the pH, ash, and reducing ar content to the presence of honeydew.

TABLE 8. Average Composition of Honeydew and Ranges of Values for 14 Samples (White et al, 1962)

	Average	Standard Deviation	Range
Color	Amber		Ex. Lt. Amber to Dark
Moisture (%)	16.3	1.74	12.2 — 18.2
Levulose (%)	31.80	4.16	23.91 — 38.12
Dextrose (%)	26.08	3.04	19.23 — 31.86
Sucrose (%)	0.80	0.22	0.44 — 1.14
Maltose (%)	8.80	2.51	5.11 — 12.48
Higher Sugars (%)	4.70	1.01	1.28 — 11.50
Undetermined (%)	10.1	4.91	2.7 — 22.4
pH	4.45		3.90 — 4.88
Free Acid (meq./kg.)	49.07	10.57	30.29 — 66.02
Lactone (meq./ kg.)	5.80	3.59	0.36 — 14.09
Total Acid (meq./kg.)	54.88	10.84	34.62 — 76.49
Lactone/Free Acid	0.127	0.092	0.007 — 0.385
Ash (%)	0.736	0.271	0.212 — 1.185
Nitrogen (%)	0.100	0.053	0.047 — 0.223
Diastase	31.9[1]		6.7 — 48.4

Based on four samples only.

The sugars of stored honeydew appear to be even more complex than hose of honey, perhaps since two sets of enzymes, those of the hemip-erous insect and of the honey bee, are involved in honeydew stores. Sev-:ral investigators have studied the sugars of honeydew as excreted by the nsects, using modern methods of analysis. Levulose, dextrose, and melezi-:ose have long been known. Gray and Fraenkel (1953) found erlose (fruc-:omaltose) in several honeydews. Duspiva (1954) found, in addition, a series of higher sugars related to erlose by the successive stepwise addition of glucose molecules. This was confirmed by Wolf and Ewart (1955). Bacon and Dickinson (1957) presented evidence that the melezitose com-mon to many honeydews does not arise from the plant as previously be-lieved but is produced from plant sap sucrose by an enzyme in the aphid involved. To the best of our knowledge, melezitose has never been isolated directly from a plant source. Thus it appears that there are (at least) two types of honeydew: the melezitose types, which can granulate rapidly, even in the comb; and the erlose type, which does not granulate.

The unsuitability of honeydew as winter stores for bees has generally been ascribed to melezitose and "dextrins." Temnov (1958), however, lays the toxic effects of honeydew principally to the mineral salts it contains, especially potassium. Addition of the salts contained in honeydew to floral honey or sirup was found to make them also unsuitable for wintering.

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